

Synoptic Estimates of Waves and Currents via Real-Time Assimilation of In-Situ Observations

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LONG-TERM GOALS

The long-term goal of this effort is to develop a methodology to monitor near-shore waves and currents over large spatial scales using data from in-situ sensors.

OBJECTIVES

The proposed program will develop the capability of monitoring nearshore waves and currents over large scales, and will allow the timely use of information from in-situ sensors. The specific objectives to be addressed are to: 1. Develop a near-real-time capability for assimilating single- or multiple-point in-situ observations into a phase-resolving wave model; 2. Test and validate the methodology against both simulated data and archival field data for both simple and complex beach types; and 3. Conduct a full-scale test of the methodology by applying it in near-real time to a comprehensive field experiment on complex topography.

APPROACH

The procedure being developed makes use of a variational data assimilation capability for the extended-Boussinesq wave model of Wei *et al.* (1996). The approach is to use time-series data from instruments in the interior of a region to estimate the time-dependent boundary conditions for the Boussinesq model at the boundaries of the region. These boundary conditions will yield a Boussinesq-model prediction, which matches the data.

WORK COMPLETED

The work completed during the past fiscal year includes development of the mathematical framework for the assimilation procedure, improvements in the numerical implementation of the extended Boussinesq model and its adjoint, and addition of improved wavemaker and run-up models in the parallel Boussinesq code.

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RESULTS

The objective of this program is to develop a methodology to use in-situ, time-series observations from the interior of a near-shore region to determine the time-dependent boundary conditions to be applied to an extended Boussinesq wave model to reproduce the observed wave field.

During the past year the main issues addressed have been improvements to the numerical implementation and the physical modeling in the parallel Boussinesq code. The basic time-stepping scheme introduced by Wei *et al.* (1996) has been retained, but the accuracy of the spatial derivatives used on the right-hand side of the equations has been increased to fourth order, now used everywhere but in the mixed spatial/temporal derivatives which contribute to the dispersive terms, which remain second order approximations. In addition, a dealiasing filter has been implemented to limit the generation of high-wavenumber noise, caused by the nonlinearities in the equations. This filter removes energy at wavenumbers greater than two-thirds of the Nyquist wavenumber, and is applied every time step. This eliminates, at the source, the energy, which accumulates at the Nyquist frequency as a result of the nonlinear terms, and is more effective than periodically filtering the solution. In addition, the parallel code has been ported from FORTRAN77 to FORTRAN90 and implemented for both SUN and Intel/Linux platforms using either the MPICH or LAM MPI (Message Passing Interface) packages.

Improvements to the physical modeling in the forward Boussinesq model code includes improvements to the run-up model, wave-breaking and bottom friction. Wave breaking and runup were initially implemented in the manner of Chen et al. (2000). Robustness of the runup model was improved by making modifications similar to the implementation used in Nwogu & Demirbilek, (2001), where the beach is treated as a porous medium, rather than slots. One of the main differences is the introduction of an increased friction/drag coefficient in the porous medium, which serves to stabilize the flow in the porous region. Minor changes in the modeling of wave-breaking involve providing a smooth transition from a non-breaking to a breaking state (i.e. a smooth transition in the eddy viscosity). In addition, the bottom-friction model has been modified as indicated above for the porous regions of the domain. Also sponge layers have been added for wave absorption at the boundaries if needed.

Figure 1 shows results from the Boussinesq model for a roughly 6 x 7 km region around the NCEX site in La Jolla, CA. The surface elevation field is shown for 17 sec monochromatic waves propagating from 295 degrees; the significant wave height is 1 m. The bathymetry used is from the NCEX survey. The depth has been limited to 50 meters, yielding a flat bottom on the Western boundary and part of the Northern boundary, where the wavemaker is located. The most obvious feature is the refraction of the waves caused by the abrupt canyon bathymetry. This causes localized reduction of the wave height at the ends of the canyons and large wave heights at the beach near Scripps pier and Black's beach. Also in evidence are the waves reflected from the canon walls.

The results shown in Figure 1 are presently being used to develop the assimilation procedure. The assimilation procedure makes use of the adjoint to the Boussinesq equations, which are implemented in a numerically similar manner to the forward Boussinesq model. Time series data from the above forward model runs are used to generate simulated data, which is presently being used to develop the in-situ data assimilation procedure.

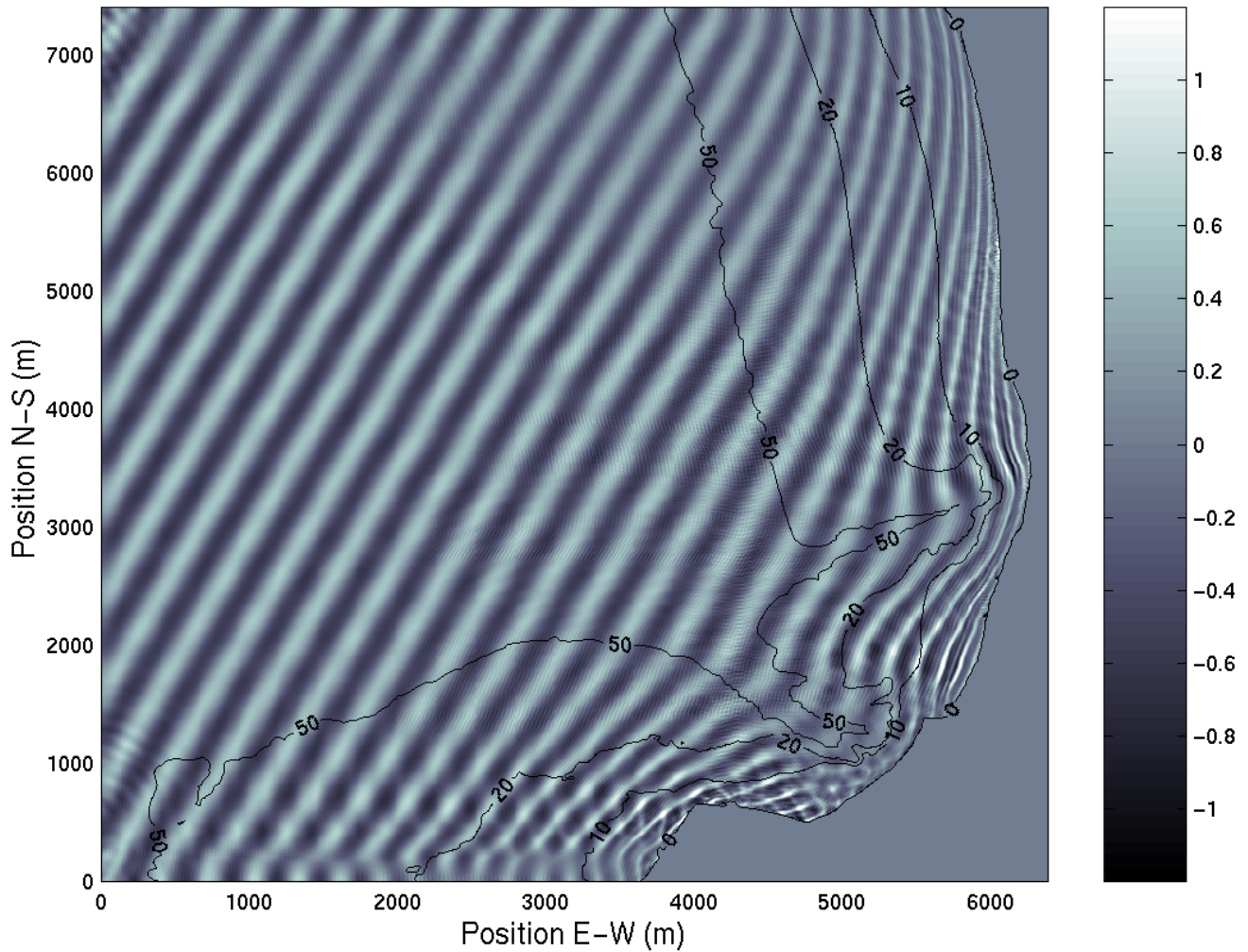


Figure 1 Surface elevation field for a 6 x 7 km region around the NCEX site in La Jolla, CA. Monochromatic waves with a period of 17 sec and a significant wave height of 1 m from 295°T are generated at the offshore boundaries. Bathymetry contours show the near-shore canyons.

IMPACT/APPLICATIONS

The potential applications of the methodology range from determining in a timely manner the conditions on a denied beach, to providing an ongoing, synoptic view of a field experiment in progress, as well as providing a tool for interrogating the near-shore hydrodynamics on beaches with high spatial variability. The results of the proposed program will provide the capability of monitoring near-shore waves and currents over large scales with greater accuracy, and allow the timely use of information from in-situ sensors.

RELATED PROJECTS

This project is part of the ONR Nearshore Canyon Experiment.

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